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THUNDERSTORM OBSERVATIONS

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Object of investigation.—Thunderstorms constitute the most impressive form of electrical discharge in nature and their various manifestations have been described from ancient times. In addition to their intrinsic interest the observation of thunderstorms and, in particular, of the lightning discharges associated with them has, in modern times, assumed a direct importance in connexion with the service provided by electrical overhead transmission systems on which lightning incidents have proved the most frequent single source of trouble. In fact, interruption of supply and damage to electrical equipment is experienced so frequently during thunderstorms that great benefit would result if methods were found to improve the safety of operation of supply systems under lightning conditions.

With this aim in mind a nation-wide investigation of lightning faults on electrical supply systems is being undertaken by the Electrical Research Association. This investigation is planned on a statistical basis, and it is clear that a correlation between lightning faults on overhead lines and the occurrence of thunderstorms constitutes one of the most important aspects of this work. The latter factor is of a meteorological nature and depends for its successs on the availability of extensive and reliable data on the occurrence of thunderstorms over the British Isles. The present notes are written with a view to acquainting meteorologists, both professional and amateur, with the object of the investigation, and to enlist the co-operation of those who may be in a position to supply future information in connexion with the above work, which is directly concerned with a matter of national importance.

Frequency of lightning flashes.—Published statistical data on the frequency of thunderstorms[1,2*] are based on the number of days on which thunder is heard, which, for any district, is called its " isokeraunic level ". This definition has been accepted internationally, but its relevance for practical

*The index figures refer to the list of references on p. 53.

problems has been repeatedly criticised. First, the isokeraunic level gives no indication of the severity of individual storms,[3] and secondly, it does not differentiate between storms producing lightning flashes which are principally confined to the clouds and those which reach earth.[4] From the view point of the protection against lightning—either of living beings, or structures, or electrical transmission systems—lightning flashes between clouds are of no direct interest.

Having regard to this importance of the frequency of occurrence of flashes to earth, critical surveys have been undertaken of relevant information.[5] From one such investigation[5] a tentative indication has been derived that, in temperate regions, the number of lightning flashes to one square mile of ground is about equal to one half of the respective isokeraunic level.

It must be emphasised that even if the foregoing relation is correct, it merely constitutes an average value taken over long periods and covering considerable areas. Now it is well known that the storm activity may vary greatly between different localities and from year to year. In fact, the severity of exceptionally heavy storms may be such as to produce, in a single day, the bulk of the total annual failures on an electrical overhead system. Thus on one system covering an area of about 1,200 sq. miles practically all faults due to lightning experienced in one year—and these amounted to over 100—occurred in the course of 2 days.

Principal types of lightning discharges.—While it is beyond the scope of these notes to discuss in detail the various types of lightning discharges which have been observed, a brief enumeration of the principal characteristics of the most common types of discharge may be of value. These can be subdivided most conveniently into discharges between cloud and earth, and discharges between different parts of a cloud.

Flashes to earth normally start inside a charge centre of a thundercloud and are propagated towards earth in the form of a so-called "leader stroke". On reaching earth the leader stroke, which can only be detected by means of fast-moving cameras, is followed by the main "return stroke" which follows in every detail the trail blazed by the leader stroke and which, on account of the high current discharged through it, constitutes the path visible to the unaided observer. About one half, roughly, of such flashes to earth are confined to a single discharge channel (Fig. 1), while the other half shows more or less pronounced branching, forked lightning (Fig. 2). As the direction of branching of electrical discharges is independent of polarity and always occurs in the direction of the initial propagation of the discharge, branches of normal lightning strokes to earth are always inclined downwards.

In contradistinction to the foregoing normal flash to earth, flashes to very tall earthed objects, such as wireless masts, balloon cables and so on, may be initiated at the top of the structure from where the usual leader stroke would then be propagated towards the cloud, while the return stroke would flow from the cloud towards the structure. Branching in this case would be directed upwards.

Multiple-stroke flashes to earth (Figs. 3 and 4), which may occur in both the foregoing cases, are characterised by the repetition of the leader and return stroke process described above, along the original discharge path. Occasionally one of the later strokes in such a flash may follow an alternative branch near

earth, thus giving a still picture of a bright forked flash to earth. Such multiple-stroke flashes may discharge up to twenty or more individual strokes covering a total duration of about a second, and they can be recognised by a pronounced flicker of the discharge. They are believed to be caused by the tapping of surrounding cloud-charge centres, the distances between which may be several miles, i.e. several times the distance covered by the initial discharge to earth. A multiple-stroke flash can therefore consist of a discharge to earth together with long and more or less horizontal discharges in or just below the cloud.

FIG. 1—SINGLE UNBRANCHED FLASH

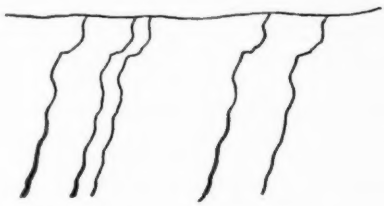

FIG. 3—MULTIPLE-STROKE FLASH UNBRANCHED RECORDED WITH MOVING CAMERA

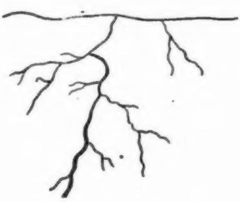

FIG. 2—SINGLE BRANCHED FLASH

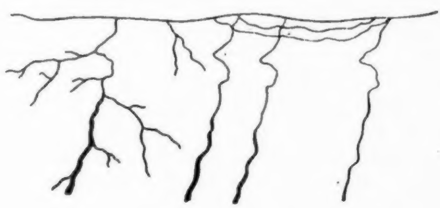

FIG. 4—MULTIPLE-STROKE FLASH BRANCHED RECORDED WITH MOVING CAMERA

Cloud-to-cloud flashes are less susceptible to visual or photographic investigation than flashes to earth and less is known about them. The term, cloud-to-cloud flashes embraces a variety of discharges between different charge centres in a thundercloud or even from the cloud into the upper atmosphere. However, for the present purpose no further subdivision is necessary as the immediate interest is concentrated on flashes reaching earth.

Sound of thunder.—In the sound of thunder produced by a normal lightning discharge two types can sometimes be distinguished: a short sharp crack and the familiar long-drawn rumbling.

The sharp crack of thunder which has frequently been described in literature[4] is produced by the compression wave caused by the sudden expansion of the discharge channel during the heavy return stroke. This sound is rapidly attenuated with distance and is absent in cloud-to-cloud discharges. It is particularly noticeable in lightning flashes which strike earth at a short distance from the observer.

While the violent sharp crack will be recognised without difficulty by any observer who has experienced flashes to earth within a few hundred feet, it should not be mistaken for a swishing noise which frequently precedes a thunder clap. This latter is likely to be produced by discharges which may only be visible at

night, and which arise from pointed earthed bodies as a result of the sudden field change caused by a lightning discharge. As these field changes are propagated with the speed of light (186,000 mi./sec.), whereas ordinary thunder is propagated with the speed of sound (1,085 ft./sec.), the swishing sound reaches the ear of an observer well in advance of the proper thunder clap. However, since the field changes caused by flashes to earth and by cloud-to-cloud flashes are of a similar order of magnitude, the swishing sound cannot be used to differentiate between these two types of discharge.

The well known rumble of thunder is due to the great distances covered in the cloud by some lightning discharges to which reference has already been made. As the duration of even the longest discharge rarely exceeds 1 sec. this is negligibly small compared with the time taken by the thunder to reach an observer who may be close to one end of a discharge but possibly 5 to 10 miles away from its other end in the cloud.

It thus appears that a sudden crack followed by the ordinary rumbling noise can be taken as an indication of a lightning flash to earth, but its value as a means of recognising such discharges is limited by the comparatively short distances over which it can be recognised.

Methods of recording lightning flashes.—The problem of reporting the occurrence of thunderstorms producing lightning discharges to earth would be greatly simplified if methods for automatic recording were available. Several kinds of instruments designed for specific purposes are in existence which record thunderstorms up to great distances. These are based fundamentally on three major principles: the recording by means of an electrometer-type of instrument[8,9] or by a cathode ray oscillograph[10,11] of electric field changes produced by lightning discharges, the reception on a selected wavelength of the atmospherics[12] produced by lightning discharges, and the recording of the current discharged into the atmosphere from a fine earthed point[13,14] installed at some height above earth.

Each of these instruments has, in its own field of application, greatly extended our knowledge of lightning phenomena, but none of these methods can be applied to the problem under discussion. The last-named methods are so far incapable of distinguishing between cloud-to-cloud flashes and flashes to earth, while the first method involves prohibitive expense in addition to technical complications.

Proposed census of thunderstorms.—From what has been said above it follows that no simple instrument is available by which to differentiate between cloud-to-cloud flashes and flashes to earth. In these circumstances it is necessary to seek the help of voluntary observers who have contributed so much to the statistical information from which most meteorological data have been obtained.

For the convenience of those who may be willing to co-operate in the work outlined, postcards will be provided on which the following information will be requested:—

(1) Approximate time and duration of storm.
(2) Direction of movement of storm.
(3) Severity of storm.
(4) Estimate of number of lightning flashes to earth.

The following comments may be pertinent in connexion with the individual items mentioned.

The approximate time and duration of storm is intended to serve as a means of correlating and checking the times of failures of electricity supply reported by supply undertakings.

The direction of movement of storm will provide an indication of storm movements in areas with a low density of observers.

The severity of the storm cannot be readily defined, but an observer should find no difficulty in making brief qualitative statements, such as: a few rumbling noises of distant thunder, a few lightning flashes with lengthy time intervals, continuous lightning activity during the passage of thunderclouds, several intense flashes of lightning from a local stationary cloud, violent and prolonged lightning activity which was first noticed at a distance, then proceeded overhead, and finally disappeared in the direction mentioned under (2), etc.

An estimate of the number of lightning flashes to earth would be most valuable for the present investigation, but may undoubtedly be open to considerable ambiguity. Such an estimate is necessarily influenced by the field of vision of the observer, by the time of day or night of the occurrence of the storm, by the height of the thundercloud, and by visibility and other atmospheric factors, all of which may reduce the chance of observing flashes to earth. While these difficulties are recognised it should be emphasised that the information requested is not intended to be used for a statistical evaluation of the density of lightning flashes to earth, but as an indication of the potential danger of the particular storm to any electrical overhead line in the area concerned. Thus it will be sufficient to give, under this heading, general statements like: no flashes to earth noticed, a small percentage of the flashes went to earth, few but distinct flashes to earth, many flashes to earth, etc. If in addition an approximate indication can be given of the number of flashes to earth, *e.g.* so many strokes to earth per minute, during the height of the lightning storm, this information in conjunction with the total duration of the storm will be most valuable for the purpose of this investigation.

Conclusions.—Valuable information on the behaviour of different types of electrical transmission lines under lightning conditions can be obtained if the number of faults due to lightning on any particular line can be correlated with the lightning activity of the area concerned. Statistical information on lightning faults on electrical supply systems is being collected. To obtain the complementary information on the occurrence and severity of lightning storms an appeal is made for the co-operation of observers in England, south Scotland and Wales. Interested potential observers are requested kindly to write to the British Electrical and Allied Industries Research Association, 5 Wadsworth Road, Perivale, Middlesex.

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LONDON TEMPERATURES

BY W. A. L. MARSHALL

The bourdon tube of the mercury-in-steel distant recording thermograph from which the temperatures on the roof of the Meteorological Office, Victory House, Kingsway, London, are supplied to the Press is exposed in a small Stevenson screen, 122 ft. above street level and 3 ft. above a short parapet to which the screen is bolted. An iron rail 1 ft. 9 in. above this parapet is 6 in. clear of the back of the screen about on a line with the top of the legs. A higher parapet 4-ft. high lies about 40 ft. to the west of the screen. The roof is flat.

The screen is very openly exposed in all directions except to south-south-west, where a projection of the main building 8-ft. high is situated about 45 ft. away; there is no higher roof in the immediate locality. There is no special insulation between the asphalt-covered roof and the wooden legs of the screen. The nearest skylights, opaque and dull, are 20-ft. to the west of the screen.

Thus hourly roof temperatures are available at any time of day or night, a facility that has resulted in their being very widely quoted. The roof exposure, however, differs so substantially from an orthodox exposure that an examination of the extent to which these roof values differ from readings taken at a standard site in inner London is desirable. Maximum and minimum temperature readings at Kensington Palace have been issued as official " London Observations " for many years. Kensington Palace values have therefore been taken as comparable for this purpose, the period reviewed being the twelve months August 1946 to July 1947.

Over the twelve months examined the maximum temperature on the asphalt roof of the Meteorological Office was lower than the maximum temperature on the orthodox site at Kensington Palace from early summer until late autumn. This difference was most pronounced from August to October though there was one occasion in June when the roof was six degrees cooler than near the ground.

From late November to January, however, the trend was different. Maximum temperature was often higher on the roof than near the ground, once by as much as 8°F. This feature was noticeable to a lesser extent in March also. February 1947 was exceptionally cold. In a more normal season the tendency for winter maxima to be higher on the roof than near the ground may hold good from November to March.

The two cases in which day-maximum temperatures on the roof of the Meteorological Office, Kingsway, differed by six degrees or more from the readings at Kensington Palace were December 13, 1946 (V.H. max. = 47°F., K.P. max. = 39°F.) and June 12, 1947 (V.H. max. = 62°F., K.P. max. = 68°F.)

> December 13 was a foggy day in the London area, the fog varying in persistence and intensity. At Kew Observatory, where dense fog persisted all day, the maximum temperature was only 36°F., yet at Croydon there were 4 7 hr. of bright sunshine after early morning fog and the temperature there reached 46°F. On the roof of Victory House temperature rose from 36°F. at 0900 G.M.T. to 47°F. at 1400, while visibility improved from 50 yd. at 0900 to 500 yd. by midday.
>
> June 12 was a sunny day but with moderate easterly winds. Maxima in the London area ranged from 62°F. at Croydon and Hampstead to

67°F. at Camden Square. Temperature on the roof of the Meteorological Office rose to 62°F. at 1300 G.M.T. and remained steady until it commenced to fall soon after 1500.

The reason for the above facts is not obvious. In summer the effects of the asphalt roof seem to be more than offset by the effects of height and the more open exposure on the roof than is possible at ground sites in inner London.

TABLE I—DAY-MAXIMUM TEMPERATURE

0900–2100 G.M.T.

	Monthly means		
	Victory House (V.H.)	Kensington Palace (K.P.)	V.H.—K.P.
	°F.	°F.	°F.
1946			
August	67·9	69·3	−1·4
September	64·5	65·9	−1·4
October	56·1	57·6	−1·5
November	52·4	52·7	−0·3
December	43·5	42·6	+0·9
1947			
January	41·4	40·5	+0·9
February	33·0	33·5	−0·5
March	47·2	46·7	+0·5
April	58·0	58·3	−0·3
May	67·3	68·1	−0·8
June	71·2	72·3	−1·1
July	74·2	75·2	−1·0
Year	56·5	57·0	−0·5

Daily difference (V.H. — K.P.)

Difference (V.H. — K.P.)	1946 Aug.	Sept.	Oct.	Nov.	Dec.	1947 Jan.	Feb.	Mar.	Apr.	May	June	July	Total	
°F.	*Number of occasions*													%
+8	—	—	—	—	1	—	—	—	—	—	—	—	1	0·3
+7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+5	—	—	—	—	2	1	—	—	—	—	—	—	3	0·8
+4	—	—	—	2	1	2	—	—	—	—	—	—	5	1·4
+3	—	—	—	—	1	1	—	2	—	—	—	—	4	1·1
+2	—	—	—	2	2	8	1	5	1	—	—	—	19	5·2
+1	—	1	1	3	7	7	3	6	5	3	1	2	39	10·7
0	3	5	3	7	10	3	10	11	12	10	7	11	92	25·2
−1	16	12	12	10	7	7	11	7	8	10	16	8	124	34·0
−2	10	7	10	4	—	2	2	—	3	6	3	6	53	14·5
−3	1	3	2	2	—	—	1	—	1	1	1	4	16	4·4
−4	1	2	3	—	—	—	—	—	—	1	1	—	8	2·2
−5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−6	—	—	—	—	—	—	—	—	—	—	1	—	1	0·3

In the last few months of the year, when the general trend of temperature is downward, a massive object such as Victory House, by reason of its thermal capacity may have introduced a certain amount of seasonal lag. This may account in part for the relatively higher maxima on the roof in November and December. Victory House was centrally heated during the day-time from the beginning of October until the end of April. This had no appreciable effect on the maximum temperature on the roof in October, and there is thus no reason

to suppose that it had any large effect on the maxima on the roof during the remainder of the winter period.

The severe winter of 1946-7 affords an opportunity of comparing the number of occasions on which frost persisted all day on the roof and near the ground.

TABLE II—FROST PERSISTING THROUGHOUT THE DAY

Maximum temperature 32 F. or below

Day maximum	December V.H.	December K.P.	January V.H.	January K.P.	February V.H.	February K.P.	March V.H.	March K.P.	Winter 1946–7 V.H.	Winter 1946–7 K.P.
°F.	*Number of occasions*									
32	—	—	1	—	3	4	1	—	5	4
31	—	1	1	3	4	3	—	—	5	7
30	1	—	1	2	3	6	—	—	5	8
29	—	—	2	—	4	—	—	—	6	—
28	—	—	1	—	—	1	—	—	1	1
27	—	—	—	1	2	—	—	—	2	1
26	—	—	1	—	—	—	—	—	1	—
Total	1	1	7	6	16	14	1	—	25	21

TABLE III—SPELLS OF TWO OR MORE CONSECUTIVE DAYS OF PERSISTENT FROST

Duration	January V.H.	January K.P.	February V.H.	February K.P.
days				
3	—	—	1	2
4	—	—	1	—
5	—	1	—	—
6	1	—	—	—
7	—	—	—	—
8	—	—	—	1
9	—	—	1	—

Frosty days were more frequent and more severe on the roof of the Meteorological Office than at 4 ft. above the ground at Kensington Palace.

TABLE IV—NIGHT-MINIMUM TEMPERATURE

2100—0900 G.M.T.

Monthly means

	Victory House (V.H.)	Kensington Palace (K.P.)	V.H. – K.P.
	°F.	°F.	°F.
1946			
August	55·9	54·0	1·9
September	55·0	53·6	1·4
October	48·6	46·9	1·7
November	46·2	44·4	1·8
December	37·3	33·7	3·6
1947			
January	35·5	32·9	2·6
February	29·0	27·8	1·2
March	38·4	35·9	2·5
April	45·4	42·9	2·5
May	52·4	49·9	2·5
June	58·8	55·1	3·7
July	61·2	58·8	2·4
Year	47·1	44·8	2·3

[To face p. 56

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THERMOMETER SCREENS ON ROOF OF VICTORY HOUSE, KINGSWAY
looking south-east

To face p. 57]

Reproduced by the courtesy of R. K. Pilsbury

METEOROLOGICAL ENCLOSURE, KENSINGTON PALACE GARDENS
looking north-west

Daily differences (V.H.—K.P.)

Difference (V.H.—K.P.)	1946 Aug.	Sept.	Oct.	Nov.	Dec.	1947 Jan.	Feb.	Mar.	Apr.	May	June	July	Total	%
°F.	*Number of occasions*													
+10	—	—	—	—	—	1	—	1*	—	—	—	—	2*	0·5*
+9	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+8	—	—	1	—	2	1	1	—	—	—	1	—	6	1·6
+7	—	—	—	—	2	—	1	1	1	1	5	—	11	3·0
+6	2	—	1	3	4	1	—	2	3	1	2	—	19	5·2
+5	—	1	1	—	3	4	—	—	1	3	—	1	14	3·8
+4	2	3	3	5	3	3	—	3	3	2	5	5	37	10·1
+3	4	2	3	3	3	1	1	4	5	7	6	8	47	12·9
+2	6	4	4	4	8	9	4	8	6	7	7	10	77	21·1
+1	13	13	10	2	5	7	9	8	8	6	3	5	89	24·4
0	4	7	4	10	1	3	10	3	1	4	1	2	50	13·7
−1	—	—	4	3	—	—	2	1	2	—	—	—	12	3·3
−2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−4	—	—	—	—	—	1*	—	—	—	—	—	—	1*	0·3*

*Doubtful.

The two occasions on which the minimum temperatures on the roof of the Meteorological Office were 10°F. higher than the reported readings at Kensington Palace were January 3, 1947 (V.H. min.=39°F., K.P. min.=29 F.) and March 15, 1947, (V.H. min.=32 F., K.P. min.=22°F.).

The Kensington-Palace value of 29 F. on January 3 is supported by the values at other London observing stations. The value of 22°F. on March 15 is doubtful, all other London ground-level stations reported minima of between 25 F. and 27°F.

The case in which the Meteorological Office night-minimum temperature was four degrees lower than that reported at Kensington Palace was on January 1, 1947, (V.H. min.=37°F., K.P. min.=41 F.). The Kensington 9 a.m. dry-bulb reading was 32°F., a ten-degree error seems to have been made in reading the minimum-temperature thermometer there.

Night-minimum temperatures were consistently higher on the roof than at 4 ft. above the ground. This is in accordance with expectations from considerations of height alone. There was no central heating in Victory House at night during the winter of 1946-7, but the thermal capacity of the building may have tended to reduce the diurnal variation of temperature in its immediate vicinity, and thus have accentuated the December and January differences.

TABLE V—NIGHT FROSTS

Minimum temperature 32 F. or below

Description	Min. temperature	Oct. V.H.	Oct. K.P.	Nov. V.H.	Nov. K.P.	Dec. V.H.	Dec. K.P.	Jan. V.H.	Jan. K.P.	Feb. V.H.	Feb. K.P.	Mar. V.H.	Mar. K.P.	Winter 1946–7 V.H.	Winter 1946–7 K.P.
	°F.	*Number of occasions*													
Slight	32–30	—	1	—	—	3	7	2	5	3	5	3	7	11	25
Keen	29–26	—	—	—	—	4	4	8	7	15	16	4	1	31	28
Hard	25–21	—	—	—	—	—	2	—	2	5	2	1	5	6	11
Severe	20–15	—	—	—	—	—	—	2	1	—	1	—	—	2	2
Very severe	< 15	—	—	—	—	—	—	—	1	—	1	—	—	—	2
All frost ranges		—	1	—	—	7	13	12	16	23	25	8	13	50	68

In winter, spring and early summer roof minima were often five degrees higher than at the ground site, once by as much as 10 degrees.

Details of night frosts at the two exposures during the exceptional winter of 1946–7 are given in Tables V and VI.

TABLE VI—SPELLS OF TWO OR MORE CONSECUTIVE NIGHT FROSTS

Duration	December		January		February		March		Winter 1947	
	V.H.	K.P.	V.H.	K.P.	V.H.	K.P.	V.H.	K.P.	V..H	K.P.
Nights	*Number of spells*									
2	—	—	—	—	—	—	—	2	—	2
3	—	1	1	1	—	—	2	—	3	2
5	—	—	—	—	1	1	—	—	1	1
7	1	1	—	—	—	—	—	—	1	1
11	—	—	1†	—	—	—	—	—	1†	—
13	—	—	—	1*	—	—	—	—	—	1*
16	—	—	—	—	1	—	—	—	1	—
27	—	—	—	—	—	1‡	—	—	—	1‡

*January 21—February 2. †January 23—February 2. ‡February 11—March 9.

TABLE VII—DIURNAL TEMPERATURE RANGE

Monthly means

	Victory House (V.H.)	Kensington Palace (K.P.)	V.H. − K.P.	V.H./K.P.
	°F.	°F.	°F.	%
1946				
August	12·0	15·3	−3·3	78
September	9·4	12·3	−2·9	76
October	7·5	10·8	−3·3	69
November	6·2	8·3	−2·1	75
December	6·2	8·9	−2·7	70
1947				
January	5·9	7·6	−1·7	78
February	4·0	5·7	−1·7	70
March	8·8	10·4	−1·6	85
April	12·6	15·5	−2·9	81
May	14·9	18·2	−3·3	82
June	12·4	17·2	−4·8	72
July	13·0	16·4	−3·4	79
Year	9·5	12·2	−2·7	77

Diurnal ranges of specified amounts at Victory House

Range	1946 Aug.	Sept.	Oct.	Nov.	Dec.	1947 Jan.	Feb.	Mar.	Apr.	May	June	July	Year	
°F.	*Number of occasions*													%
28–29	—	—	—	—	—	—	—	—	—	1	—	—	1	0·3
26–27	1	—	—	—	—	—	—	—	—	1	—	—	2	0·5
24–25	1	—	—	—	—	—	—	—	—	—	1	—	2	0·5
22–23	2	—	—	—	—	—	—	1	—	2	—	—	5	1·4
20–21	1	—	—	—	—	—	—	1	4	4	2	1	13	3·6
18–19	2	—	—	—	—	—	—	—	3	2	2	4	13	3·6
16–17	6	—	—	—	—	—	—	1	3	4	5	5	24	6·6
14–15	8	1	2	—	2	1	1	3	1	4	3	5	31	8·5
12–13	1	11	1	3	1	1	2	6	7	4	2	4	43	11·8
10–11	8	4	5	2	3	3	—	1	4	3	7	6	46	12·6
8–9	1	7	6	4	1	7	1	5	2	1	1	3	39	10·7
6–7	—	2	8	7	13	2	1	2	3	2	5	3	48	13·2
4–5	—	4	6	9	4	10	5	3	2	2	2	—	47	12·9
2–3	—	1	3	4	4	4	13	7	1	—	—	—	37	10·1
0–1	—	—	—	1	3	3	5	1	—	1	—	—	14	3·8

Diurnal ranges of specified amounts at Kensington Palace

Range	1946 Aug.	Sept.	Oct.	Nov.	Dec.	1947 Jan.	Feb.	Mar.	Apr.	May	June	July	Year	
°F.	*Number of occasions*													%
30–31	—	—	—	—	—	—	—	—	—	2	1	—	3	0·8
28–29	—	—	—	—	—	—	—	—	—	2	1	—	3	0·8
26–27	1	—	—	—	—	—	—	—	2	3	3	—	9	2·5
24–25	1	—	—	—	—	—	—	1	2	1	2	1	8	2·2
22–23	2	—	—	—	—	—	1	—	3	4	—	3	13	3·6
20–21	1	—	1	—	1	—	1	—	3	2	2	5	16	4·4
18–19	2	3	3	1	1	—	—	4	2	2	2	5	25	6·8
16–17	6	6	3	2	1	1	—	2	—	3	7	5	36	9·9
14–15	8	3	—	2	2	1	—	2	6	5	3	4	36	9·9
12–13	1	4	6	2	—	4	1	3	5	1	1	2	30	8·2
10–11	8	6	3	3	7	2	—	6	2	1	5	3	46	12·6
8–9	1	1	9	4	9	6	2	1	2	1	3	2	41	11·2
6–7	—	5	2	5	3	5	2	4	1	3	—	1	31	8·5
4–5	—	2	2	8	4	10	10	3	1	1	—	—	41	11·2
2–3	—	—	2	2	2	1	10	4	1	—	—	—	22	6·0
0–1	—	—	—	1	1	1	1	1	—	—	—	—	5	1·4

Night frosts were more frequent, persistent and severe near the ground than at roof level.

With day maxima mainly lower and night minima higher on the roof than near the ground a smaller diurnal temperature range at the higher level follows automatically. Table VII shows the magnitude of the diurnal temperature ranges at the two places and their seasonal variation.

METEOROLOGICAL OFFICE DISCUSSIONS

January 19, 1948. Radiative equilibrium in the ionosphere. By R. v. d. R. Woolley (*Proc. roy. Soc., London*, A, **189**, 1947, p. 129). Opener—Dr. G. D. Robinson.

The paper is concerned with the computation of temperatures from about 100 Km. to the limits of the atmosphere, on the assumption that there is radiative equilibrium at all levels. This question inevitably involves discussion of the constitution of the atmosphere at these heights. The author, developing the methods of E. A. Milne sets up the equation of radiative equilibrium and shows the physical quantities required for a calculation of temperature at any level. These comprise the total absorption per unit volume, and the fraction of absorbed radiation converted to kinetic energy, together with boundary values of the radiative flux and a limited knowledge of the distribution of intensity of radiation with angle. All these quantities must be known for all frequencies. The remainder of the paper consists of a discussion of probable values of these quantities at various heights and consequent estimates of temperature.

In the first region considered the main absorbing agent is molecular oxygen in the dissociation continuum, and the principal infra-red radiator is considered to be water vapour. There is some discussion of the amount of water vapour in the atmosphere, and the author admits a possible tenfold ambiguity. Hettner's absorption coefficients are used, and again the author is aware of the very dubious nature of this assumption. Temperatures of the order of

1,000°A are deduced. Diurnal variation is not explicitly mentioned. The levels to which this analysis is believed applicable are between 100 and 200 Km. At higher levels atomic oxygen is the main absorbing agent (in the ionisation continuum) and the author considers that the main infra-red radiators are negative ions of nitrogen, and dust. He believes negative ions to be relatively most effective between 200 and 300 Km., and deduces temperatures of the order of 1,000°A. for these heights, increasing rapidly as the total population of particles is reduced. Very considerable assumptions regarding the absorption coefficients and the relative concentration of atomic molecules and ions of oxygen and nitrogen are involved. Basing his estimate of the available radiative surface on the observations of the intensity of the zodiacal light the author then computes the effect of dust on the temperature in the very highest regions of the atmosphere, and concludes that this temperature is unlikely to be much below 4,000°A.

There was little time to consider a most interesting section of the paper where the interrelation of temperature and constitution of the atmosphere is discussed and the equilibrium of atomic and molecular oxygen investigated. A side issue of interest to the meteorologist is the author's conclusion that dissociation of the water molecule followed by escape of hydrogen from the earth's gravitational field in the prevailing high temperatures leads to a continuous upward flux of water through the stratosphere. The magnitude of this flux will greatly affect the temperature of at least the lower ionospheric layers.

Speakers in the discussion which followed included Mr. E. Gold (who in 1909 was the first to put forward a fully developed theory of radiative equilibrium in the stratosphere), Dr. A. H. R. Goldie, Dr. J. M. Stagg and Mr. O. M. Ashford. Amongst the points raised were the author's neglect of diurnal and seasonal effects and of the possibility of large scale vertical and horizontal movements of air at certain heights, the relation of the author's views on the composition of the atmosphere to those deduced from a study of auroral spectra, and difficulties in the use of ionic recombination rates (measurable by radio methods) to estimate ionospheric temperatures. In respect of the last point reference was made to the recent results of S. L. Seaton* which conflict in some respects with those of Dr. Woolley.

METEOROLOGICAL RESEARCH COMMITTEE

The 53rd meeting of the Meteorological Research Committee was held on January 29, 1948.

Consideration was given to a new method, proposed by Prof. Simon, for obtaining samples of the upper atmosphere. Briefly the proposal envisages attaching to a radio-sonde balloon a small evacuated vessel cooled by liquid hydrogen. At a predetermined height the vessel would be opened to the outside atmosphere by a valve. The air would rush in and condense as a solid and a second valve would then close the vessel. The cooling of the vessel would ensure a sufficiently large sample being obtained. After discussion of the practical aspects of the proposal it was decided to follow up this suggestion.

*SEATON, S. L.; Temperature and recombination coefficient in the ionsphere. *J. Met., Milton Mass.*, **4**, 1947, p. 197.

Two papers by Dr. Robinson dealt with the subject of turbulence very near the ground. The author presented calculations which indicate that, in the lowest layers, the radiative transfer of heat is as important as the turbulent transfer. It follows that any work on this subject which omits consideration of the radiative transfer of heat is liable to be misleading. A proposed investigation of turbulent transfer near the ground, taking account of all relevant factors, was outlined.

Dr. Stagg presented a comprehensive account of the work done at Kew on solar radiation during the past 16 years.

Other matters discussed included the magnitude of casual variations of temperature in the free air on the basis of measurements made by Dr. Frith.

ROYAL METEOROLOGICAL SOCIETY

In presenting the Report of the Council of the Society for 1947 at the Annual General Meeting on January 21, 1948, the President, Prof. G. M. B. Dobson, referred with satisfaction, to the fact that in spite of the increase in subscription the number of fellows had increased by 75 and to the increase in the sales of *Weather*. Outstanding events were the appointment of an Executive Secretary, the exceptional success of the summer meeting, as the Navy's guests, at Portsmouth, and the formation of the Midland Branch.

There was considerable discussion over the present method of election of the new Council which was considered by some Fellows to give inadequate opportunity for the general body of Fellows to put forward new members of Council.

Messrs. Darton, meteorological instrument makers, generously offered, in 1947, two annual prizes, for the next 3 years, of instruments for presentation by the Society and the first awards were announced by the President. The first prize was awarded to Major Gunton for his work in the preparation of the *Phenological Reports* of the Society and the second to Mr. J. Paton for his work on temperature and humidity conditions in a wheat field. The President announced the Council's decision not to award the Buchan Prize in 1948, because the war had prevented much work which would need to be considered from being published as yet, but to award two prizes in the following year.

The main event of the meeting, the Presidential Address, was then delivered on "Some meteorological aspects of atmospheric pollution." In his opening remarks the President said that now the serious nature of this problem was fully recognised the Society could view with pride the fact that two of its Fellows, Sir Napier Shaw and Dr. Owens, were among the very first to protest against the increasing pollution of city air.

He went on to point out that meteorological conditions affected pollution in two ways; first, in the way in which it was removed from the air of a city and, secondly, in its interaction with fog.

He based his account of the first effect largely upon the research conducted by Dr. Meetham at Leicester, which demonstrated the importance of the vertical removal of smoke and sulphur dioxide with its dependence on the degree of turbulence and the vertical lapse rate of temperature. The Leicester work showed clearly that the amount of smoke at street level increased from the windward side to the city centre and then decreased further down wind.

The theory was confirmed by the observations of the amount of daylight received in the city compared with outside, which showed a loss of daylight increasing down wind.

Sir Napier Shaw was the first to realise the importance of lapse rate on the matter when he pointed out that an inversion or " lid " would hold the smoke down. It had been difficult to correlate the Leicester smoke observations directly with upper air temperature owing to the nearest observations of the latter being made 70 miles away at Mildenhall and in the early morning, but Dr. Dobson showed curves of the connexion between Leicester pollution and the lapse rate observed over Mildenhall, demonstrating that the two are connected in the expected manner at low wind speeds but that in winds of over 20 m.p.h. there is sufficient turbulence to remove pollution upwards whatever the lapse rate.

Finally, there was the interaction between smoke and fog since the meteorological conditions favouring fog are precisely those opposing rapid removal of smoke. The smoke particles stick to the fog droplets and a dirty unpleasant fog is the result. An interesting point in this connexion is that Shaw and Owens found that London fogs which were " black " at 9 p.m. were clean at 5 a.m., which suggests the dirty fog droplets settle out during the night. In spite of this settling out, however, fogs may exist for several days. The temperature and humidity conditions in fog were not, he considered, sufficiently fully investigated to give a complete explanation of this phenomenon. Factors to be considered were the extension of cooling upwards as the top of the fog became the main radiating surface, the development of a lapse of temperature in the fog producing some degree of turbulence to bring down water droplets, and the reduction of the rate of evaporation in city fogs, when relative humidity fell below 100 per cent., by the solution of sulphur dioxide forming sulphurous acid which was rapidly oxidised to the very hygroscopic sulphuric acid.

LETTERS TO THE EDITOR

Artificial stimulation of rain formation

May I remark upon two points in Mr. J. K. Bannon's interesting article in the August issue of the *Meteorological Magazine* on " Artificial stimulation of rain formation."

The first concerns the temperature of $-32 \cdot 2$ C. I do not wish to debate whether this is a critical temperature for the formation of ice crystals, but it is a matter of common flying experience that clouds certainly do not have to reach this temperature before moderate or heavy rain can occur. Indeed I think it is probably true to say that clouds, from which rain or snow is reaching the ground, more often than not nowhere have a temperature as low as $-32 \cdot 2$ C.

The second concerns the calculations made of the order of magnitude of the heat changes in the experiment of February 5, 1947. According to Mr. Bannon's theory each particle of dry ice cools a thin streak of air to a temperature lower than $-32 \cdot 2$ C. He then suggests that in the cooled streak of air seven eighths of the water is " quickly changed to ice." The latent heat thus released he computes to be sufficient to heat up this streak by 2 C. Thus, the streak

having been previously cooled to below $-32°C$. the net result so far is a lowering of temperature in the cloud.

The ice crystals formed will, as Mr. Bannon states, soon leave these narrow streaks by precipitation or by diffusion, and will grow at the expense of supercooled water particles. They may even " infect some of the cloud below " and cause new ice crystals to form, though it is difficult to visualise such a process. But it does not seem likely that in any region, other than the originally-cooled streaks, there will be a change of seven eighths of the available water content to ice.

It is therefore not possible to say, without further data as to the number of ice crystals formed and as to their manner of growth, whether the latent heat released will, or will not, be sufficient to offset the original cooling.

RONALD FRITH

Royal Aircraft Establishment, Farnborough, Hants., January 12, 1948

[Dr. Frith may well be correct in saying that precipitating clouds do not necessarily have to extend to the -32.2 C. level. Cwilong's experiments* were carried out in conditions not strictly comparable with those in a growing cumulus cloud, and in my original article I indicated the doubtful validity of applying Cwilong's results to convective clouds. At the time of writing that article, however, Cwilong's figures were the only definite information available on the temperatures at which ice crystals form in saturated or supersaturated air. Since then further information has come to light† which indicates that ice crystals will begin to form in growing cumulus clouds at temperatures ranging from $-6°C$. for slowly growing clouds, to -20 C. for clouds with strong vertical currents. The important point is that a certain amount of cooling is required to form ice crystals in the supercooled water cloud.

In deriving the order of magnitude of possible heat changes due to the change in state from supercooled water to ice, I did not mean to imply that seven eighths of the supercooled water drops were changed to ice only in a " thin streak," but that the change took place through an appreciable volume of the cloud (the actual words used were " the top of the cumulus cloud ") and the net heating, calculated to raise the temperature by 2 C., would be spread over all this considerable volume of cloud and not over a thin isolated trail. The 300 lb. of " dry ice " used in the particular experiment under consideration would, in vaporising, cool only 70 cu. m. of cloud by just less than 1 C. There is little doubt, however, that a very much greater volume than 70 cu. m. was affected by the " dry ice " and so the net effect of the changes may well be a heating, since the cooling power of the granulated carbon dioxide is so small.

Alternatively, fixing the attention on a small streak of ice crystals as Dr. Frith does, though for their formation this small volume must initially have been cooled to some critical temperature (which may have been -32.2 C. or higher, it is not certain), it will soon have regained by ordinary eddy diffusion the general temperature of the surrounding air (very slightly lower, it is true,

*CWILONG, B. M.; Sublimation in a Wilson chamber. *Proc. roy. Soc., London*, A, **190**, 1947, p. 137.

†See M.R.P. No. 361, 1947.

than before the sprinkling with " dry ice "), a fact perhaps overlooked by Dr. Frith; but the ice particles, once formed, will have remained and the process of change from supercooled water to ice must have gone on steadily, all the time releasing heat, until the ice particles fell because of their increasing size below the freezing level. The falling out of the crystals was, presumably, the only process which prevented the whole of the cloud from changing from supercooled water drops to ice. Not only was the heating effect of the change from water to ice probably much greater than the initial cooling by the carbon dioxide, but a large part of the heating must have been below the level of the initial cooling, since the ice crystals will have soon begun to fall. The neglect of the cooling effect of the carbon dioxide when calculating the order of magnitude of the heating by release of latent heat of fusion is therefore justified.— J. K. Bannon.]

Persistence of easterly winds

I was interested to read in " Weather of 1947 " in the February issue of the *Meteorological Magazine* the reference to the long spells of easterly wind.

Whilst at H.Q., 4 Group, York (1938-41) I was impressed by the frequency and marked persistency of easterly winds, and wondered whether this was normal. A preliminary and very rough investigation definitely indicated a progressive although irregular increase in the frequency of winds from the easterly quadrant during recent years. I did not follow up my investigation owing to pressure of work, but I do suggest that a detailed study of the airflow across the British Isles, using the observations from suitably selected stations for which observations over a long period are available, may well produce most interesting results and throw some light on a possible change of climate now taking place.

R. G. VERYARD

Organization of the Meteorological Service of Portugal

May I call your attention to an information given in the *Meteorological Magazine*, Vol. 76, 1947, p. 145, which is not entirely correct and therefore may lead to wrong conclusions.

The various meteorological services of Portugal in Europe and overseas were combined in August 1946 into a National Service, under the Prime Minister (now under the Minister for Communications), which is due to meet all the national needs in the fields of meteorology and geophysics. Since its organization, the National Service has had the responsibility for all the meteorological and geophysical activities in this country. There is no Naval Service which is independent of the National Service. Due to lack of personnel, some meteorological work is still carried out in the naval and other governmental departments, under the supervision of, and until it can be transferred to the National Service.

H. AMORIM FERREIRA

Servico Meteorologico Nacional, Lisbon, February 21, 1948

[To face p. 64

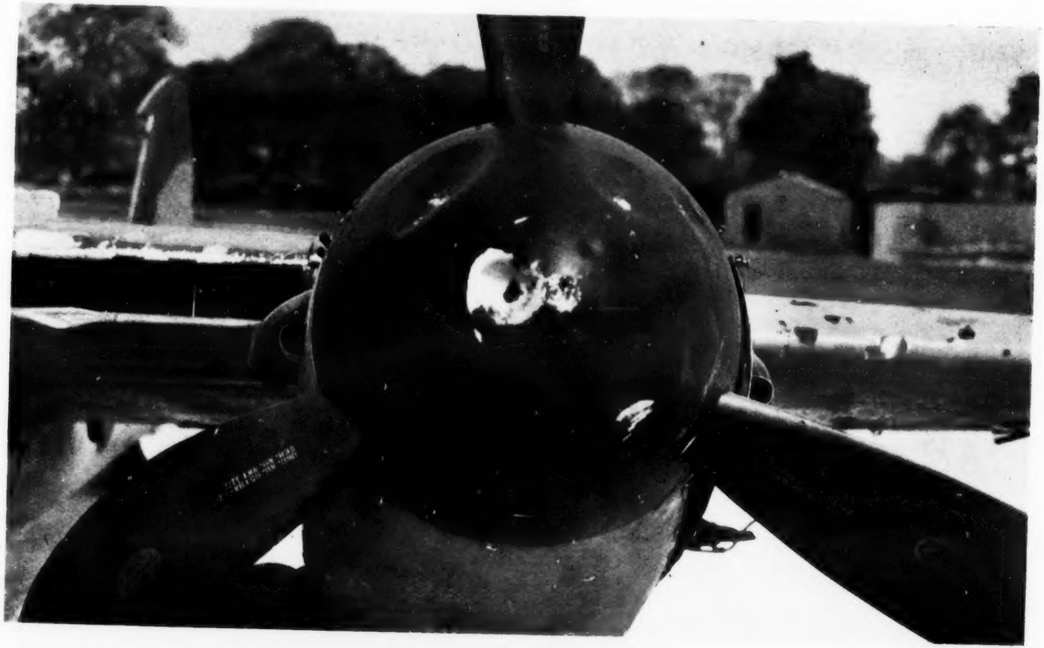

Photo by R.A.F.

HAIL DAMAGE TO PORT SPINNER OF MOSQUITO AIRCRAFT

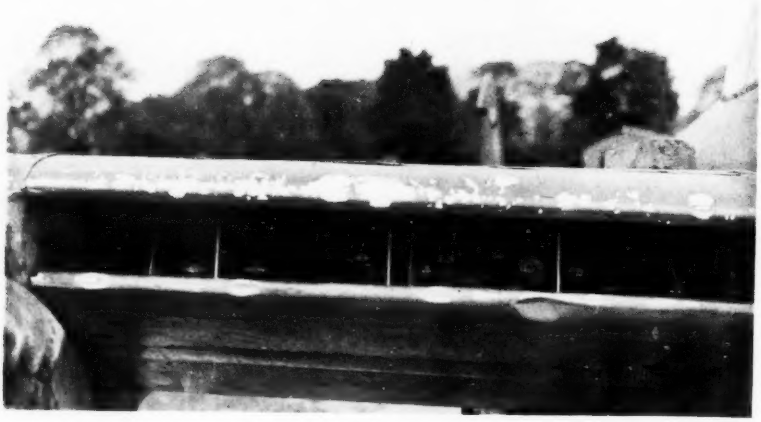

Photo by R.A.F.

HAIL DAMAGE TO RADIATOR OF MOSQUITO AIRCRAFT

Photo by R.A.F.

HAIL DAMAGE TO MOSQUITO AIRCRAFT

NOTES AND NEWS

A Violent Hailstorm in Oxfordshire on May 11, 1945

A notable hailstorm occurred in the south Midlands area in the evening of May 11, 1945. An account in the local (Oxford) Press referred to hailstones at least one inch in diameter, one of which weighed 2 oz. F/Lt. J. M. Edmonds, then of the Meteorological Office, R.A.F., Winslow, witnessed the storm at Bicester, and he compared the size of the hailstones to that of golf balls. F/Lt. Rigby of the same headquarters estimated a diameter of about an inch for some of the stones which fell at Padbury near Buckingham.

The quantity of water resulting from the rapid melting of the hailstones was so great as to render one of the airfields in the Oxford area unserviceable for a time. The local Press reports stated that there was extensive damage to windows, greenhouses and crops. One report said that the fall of hail was preceded by a peculiar noise in the sky like glass being broken.

A " Mosquito " aircraft from Barford St. John engaged on a local exercise flew into the storm and was severely damaged by hailstones. Holes were torn in the wings, the spinners were badly dented and the honeycomb radiators seriously damaged. The dents in the very strong honeycomb radiators measured 2 in. to 2½ in. across, and the holes in the leading edges of the wings were roughly 2 in. square with some approximately 4 in. by 3 in.

The pilot stated that on returning to base at a height of about 10,000 ft. he found large cumulonimbus cloud in the neighbourhood and decided to descend through a gap. At 5,500 ft. he found the aircraft being drawn into cloud, and after an estimated time of 30 sec. in the cloud he broke cloud at 4,000 ft. The aircraft was thrown about rather violently, and presumably turned over as the navigator's pockets were emptied of money. The direct result of the damage was to increase the stalling speed necessitating landing at a higher speed than usual, as a result of which the aircraft overshot the airfield, but fortunately there was no serious injury to pilot or navigator.

The storm was first reported south of Oxford and travelled almost due north reaching its climax at Kidlington between 1630 and 1715 G.M.T.

A depression to the south-west of the Bay of Biscay was filling up slowly and was surrounded by unstable air. The surface pressure gradients over southern England were rather weak, the low-level winds being mainly south-easterly about 15 kt. The upper winds veered to southerly about 20 kt. at 6,000 ft. and south-south-westerly at higher levels increasing to about 40 kt. at 20,000 ft.

Inspection of the upper air temperatures from the Larkhill radio-sondes on May 11 showed that a surface temperature of about 79°F. would suffice to initiate convection clouds extending to very high levels. Such temperatures were realised over central southern England by about 1500 G.M.T., while the falls of pressure during the afternoon resulted in the formation of a small heat low in this area. The storms broke out at about 1600 G.M.T.

OBITUARY

F/Lt. G. R. Mason, B.Sc. We report with deep regret the death of F/Lt. G. R. Mason who served in the Meteorological Branch, R.A.F.V.R., from 1939 to 1945. F/Lt. Mason graduated at the University of Leeds in 1927 with first-

class honours in Mathematics and joined the examining staff of the Patent Office.

He volunteered for the Meteorological Branch of the R.A.F.V.R. on its formation in the summer of 1939 and was called up for training following the outbreak of war in September.

F/Lt. Mason was a forecaster for periods at H.Q.2 and H.Q.3 Group but the greater part of his service was rendered overseas. He was with H.Q. Air Component in France before Dunkirk and again in France with the special unit near Marseilles between Dunkirk and the French armistice. He was posted to Aden in December 1940 and was there and elsewhere in the Middle East until May 1944. He was demobilised in October 1945 and returned to his duties at the Patent Office.

F/Lt. Mason always gave of his best and earned the high opinion of his colleagues for his ability, devotion to duty and sportsmanship.

He leaves a widow and two sons to whom we offer our deepest sympathy.

REVIEWS

Long-range weather forecasts in the Netherlands. By S. W. Visser. Koninklijk Nederlandsch Meteorologisch Instituut No 102, Mededeelingen en Verhandelingen 51. 8vo. $9\frac{1}{2}$ in. $\times$ $6\frac{3}{4}$ in., pp. 143, *Illus.* 's Gravenhage 1946. 0.40 florins. Dutch with English summary.

As soon as he exceeds the period for which "extended range" inferences can be made from the daily synoptic chart, the forecaster finds himself in great difficulties. The possible factors affecting the weather of, for example, western Europe, are so many, and their connexions so obscure, that reasoning from cause and effect in physical processes breaks down, and must be replaced by groping in a dimly-lit maze of statistics. The process is very laborious; the investigation of the possibility of monthly forecasts of temperature and precipitation in Holland has occupied Dr. S. W. Visser for ten years.

He has two lines of attack; periodicities and correlation. Among the periodicities investigated are $2\frac{1}{4}$, 3, $3\frac{1}{4}$, $5\frac{1}{4}$, 6·8–7, $7\frac{1}{2}$, 8, 9, 11, 13 and 35 years, but of these only the first is found to be of any practical use; the others being either non-existent or too weak and irregular. In particular the author finds that a 3-year cycle often boils down to the fact that in a random series the average interval between maxima (or minima) is precisely 3 units. It must be remarked that the plot of even the $2\frac{1}{4}$-year cycle, Fig. 3, is far from convincing! The $2\frac{1}{4}$-year and $5\frac{1}{4}$-year cycles are both found to be widespread over the North Atlantic; the former crosses the ocean in 6–7 months, the latter in 11 years. On the basis that this ratio of 1 : 20 is also the ratio of the speeds of ocean and wind currents, he concludes that the former is wind-borne and the latter water-borne, but surely the Gulf Stream does not take 11 years to cross the Atlantic! Actually it takes 6–7 months, so that the $2\frac{1}{4}$-year cycle is the more likely to be water-borne. All the work on cycles seems to the reviewer to be rather uncritical; a systematic periodogram analysis would have been more satisfactory.

The practical results of the investigation are due mainly to the extraordinarily thorough work on correlation. Rainfall of Holland and temperature at De Bilt were correlated month by month with 17 other variables, with lags of one to 12 months—144 coefficients for each combination of two variables. When

the significant coefficients have been selected, their interrelations still have to be eliminated by partial correlation. Eventually eleven factors are selected as the basis of regression equations; these are: rainfall at Paramaribo, temperature at Ivigtut and De Bilt, pressure at Ponta Delgada, Reykjavik, Helsinki and Berlin, pressure difference Ponta Delgada-Reykjavik and Berlin-Helsinki, variability of sunspots and the 2¼-year cycle. It is noteworthy that the effect of Arctic ice is not included; the author appears to be unaware of the extensive work done in the British Meteorological Office about 1928 on this important factor.

Each regression equation contains five or six of these eleven independent variables and the " multiple correlations " between computed and observed values of rainfall range from 0·705 to 0·847, and of temperature from 0·694 to 0·845.

These final results seem at first sight to be very satisfactory, but on consideration doubt creeps in. To begin with, the effective measure of the part played by one variable in the irregularity of another is not the correlation coefficient between them but its square, so that the real measure of success ranges from less than three quarters to less than half. More serious is the fact that the regression equations are based on the highest coefficients selected from a very large number, apparently solely on the criterion of magnitude. The author examines their relation to their probable errors, but he calculates the latter by the expression for coefficients of zero order, overlooking the fact that the effective number of observations decreases by one for each step in partial correlation. As there are only 39 observations to begin with, this increases the probable errors considerably. It is almost certain that several of the relationships used in the regression equations are due to chance or are much smaller than the coefficients suggest. This point may be illustrated by the coefficients of sunspot variability in January with rainfall 5, 6, 7, 8 and 9 months later: + ·16, − ·40, + ·26, − ·48, + ·04. The two negative coefficients are regarded as highly significant and used in the forecasting equations, but to the reviewer they seem merely the results of chance !

The author claims considerable success for " forecasts " obtained by comparing the observed and calculated values for the period investigated (1901–39). This, however, means little; in such a test a temporary agreement arising by chance will appear just as good as a real permanent relationship. The real test comes when the equations are applied to years outside the period on which they are based. The author made two such tests: of 1881–1900 he says " The success was not in all respects satisfying, the number of failures being too large. The cause of this result is due to the climate break of Schmauss." For 1940–4 on the other hand he claims much greater success. Table LXX gives the results of 15 comparisons, of which eight were successful, one partially successful and six failed. The criterion of success is that the forecast value differs from the observed by less than the standard deviation of the latter; with such a criterion a forecast of " normal conditions " would succeed two times out of three. The signs of the forecast and observed deviations agreed on eight occasions and differed on seven.

This account of a very painstaking research may appear to be unduly critical, but the criticisms are meant in a helpful spirit. It is by such patient work that progress is made, and the basis laid down for greater success in the future.

C. E. P. BROOKS

A method for determining the daily variation in width of a shadow in connection with the time of the year and the orientation of the overshadowing object. By R. J. v. d. Linde and J. P. M. Woudenberg. Koninklijk Nederlandsch Meteorologisch Instituut. No. 102, Mededeelingen en Verhandelingen 52. 8vo, $9\frac{1}{2}$ in. × $6\frac{3}{4}$ in., pp. 7. *Illus.* 's Gravenhage, 1946. 0.40 florins. Dutch with English summary.

This publication contains diagrams giving a neat and rapid solution to the problem of finding the breadth of shadow cast by a straight hedge on to level ground. If as seen from a point on the shadow edge the altitude of the sun is α and the angle between the normal to the hedge and the bearing of the sun is β then the ratio S/h of breadth of shadow to height of hedge is equal to $\cot\alpha\cos\beta$

Two diagrams are necessary. The first of these has a grid with altitude of the sun as ordinate and azimuth of the sun as abscissa measured east and west from the south point both on a scale of 5° per cm. Traced on this grid are the tracks of the sun as seen from the latitude of Amsterdam for the 20th or 21st of each month and isopleths of time for every half hour. Separate diagrams are needed for the first and second halves of the year because of the difference in the equation of time.

The second diagram, printed on transparent paper, has a grid on the same scale as the first with altitude as ordinate and azimuth as abscissa, and carries isopleths of the values of S/h ranging from 8/1 to 1/16. It is symmetrical about the central vertical line.

If now the breadth of shadow of a hedge, such that the normal to it drawn towards the south has azimuth A, is required the second diagram is placed on the first so that the bases coincide and the mid point of the base of the second is on the point A° of the first. Thus, in the case of a hedge extending from north-west to south-east the second diagram would be placed with the mid point of its base on the point azimuth 45° west of south on the base of the first diagram. The date and time are pinpointed on the first diagram and the ratio S/h read off between the isopleths on the second one.

Over most of the first diagram the isopleths of months and half hours form a roughly rectangular grid of sides about 1·5 by 2 cm. It should be possible to pinpoint the sun's position within a degree in both altitude and azimuth even though the scales are by no means linear in date and time.

It would have been useful if the authors had provided a statement of the error which might occur in the estimation of the final result consequent on a small error in pinpointing the date and time. A little algebra shows that fortunately the errors are least when the sun is high in the sky and exactness is most necessary.

G. A. BULL

ERRATUM

January 1948, page 11, equation (6)

$$\textit{for} \quad \frac{H}{H} = -\left(a + \frac{bH}{2}\right)$$

$$\textit{read} \quad \frac{\delta H}{H} = -\left(a + \frac{bH}{2}\right)$$

Unsettled conditions prevailed throughout the month with depressions or troughs of low pressure passing over or near the British Isles. The mean pressure for the month (Fig. 1) showed a deep depression centred south of Iceland

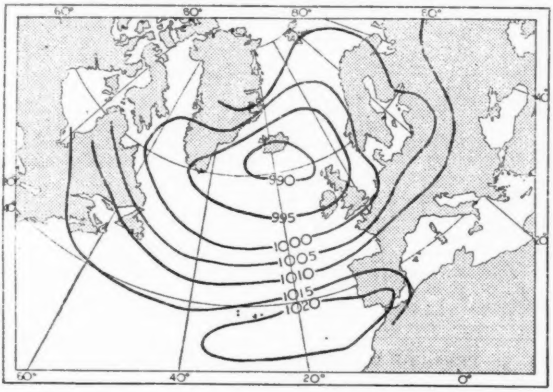

FIG. 1—MONTHLY MEAN PRESSURE, JANUARY 1948

and extending from south Greenland to Norway and southward to the English Channel. Pressure at the centre was below 990 mb. An anticyclonic belt, pressure over 1020 mb., extended from south-west of the Azores to Gibraltar; 1020 mb. was exceeded also over much of the eastern United States and the Great Lakes. Pressure was below the average (Fig. 2) from the West Indies

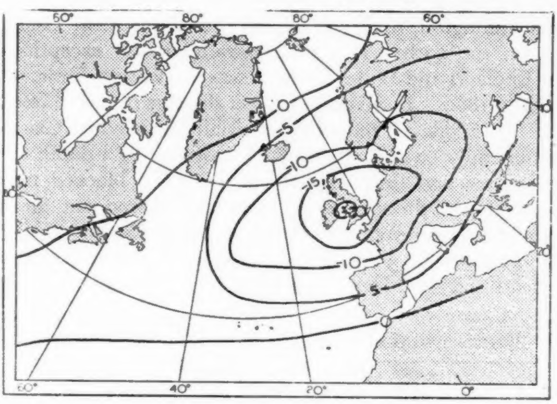

FIG. 2—PRESSURE DIFFERENCES FROM NORMAL, JANUARY 1948

across the Atlantic and Europe to Russia, and slightly above the average over the eastern states of North America and Canada as well as north of the Arctic Circle and in the neighbourhood of Madeira. The deficiency was greatest over the central area of the British Isles where it amounted to approximately 20 mb. The nearest approach to the distribution of the deviations from

normal pressure that could be found occurred as long ago as January 1930, the chart for which month is given in Fig. 3.

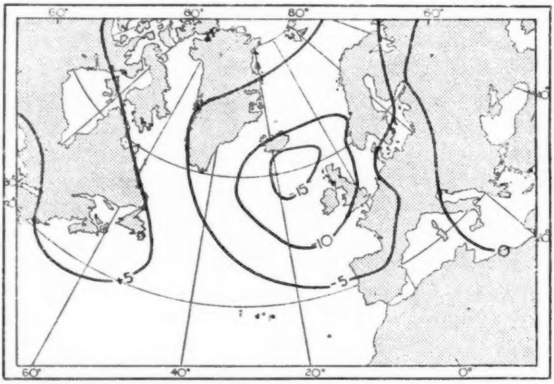

FIG. 3—PRESSURE DIFFERENCES FROM NORMAL, JANUARY 1930

In the British Isles the weather was very unsettled and excessively wet, with frequent strong winds and local gales. Mean pressure was exceptionally low; at such widely separated stations as Oxford and Southport it was the lowest on record for any month. In Scotland and Northern Ireland the weather was cold but in England and Wales it was generally rather mild. The deviation from the average temperature ranged from −2·4°F. in north Scotland to +3·3°F. in south-east England. The extreme temperatures for the month were 60°F. at Cannington, Somerset on the 3rd and 4°F. at Logie Coldstone, Aberdeenshire on the 24th. The general rainfall was exceptionally heavy, particularly in England and Wales where it was the wettest January in a record which goes back to 1869. Local snow or sleet showers occurred frequently from the 5th—28th. In Scotland, moderate snowfall occurred in Caithness on the 9th and more generally on the 17th—18th; snow lay to a depth of from six to nine inches in places and drifts five to six feet deep blocked main roads in central districts. Local thunderstorms were rather frequent for the time of year. The month was stormy, with frequent strong winds and gales; a mean hourly velocity of more than 38 m.p.h. was measured at the anemometer stations at St. Ann's Head and St. Mary's, Scilly on as many as 15 days and 13 days respectively.

The general character of the weather is shown by the following table :—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	60	21	+2·0	234	+8	80	15
Scotland	55	4	−1·7	162	+3	82	14
Northern Ireland ..	55	21	−1·3	196	+5	95	17

RAINFALL OF JANUARY 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square	3·61	194	*Glam.*	Cardiff, Penylan	8·56	232
Kent	Folkestone, Cherry Gdns.	3·87	172	*Pemb.*	St. Ann's Head	7·32	210
,,	Edenbridge, Falconhurst	4·78	195	*Card.*	Aberystwyth	5·13	159
Sussex	Compton, Compton Ho.	7·54	237	*Radnor*	Bir. W. W., Tyrmynydd	15·75	250
,,	Worthing, Beach Ho. Pk.	4·74	203	*Mont.*	Lake Vyrnwy	17·74	320
Hants.	Ventnor, Roy. Nat. Hos.	6·40	249	*Mer.*	Blaenau Festiniog	24·07	235
,,	Fordingbridge, Oaklands	5·75	208	*Carn.*	Llandudno	5·80	241
,,	Sherborne St. John	6·04	260	*Angl.*	Llanerchymedd	8·52	270
Herts.	Royston, Therfield Rec.	3·49	202	*I. Man.*	Douglas, Boro' Cem.	10·89	325
Bucks.	Slough, Upton	4·09	220	*Wigtown*	Port William, Monreith	7·63	233
Oxford	Oxford, Radcliffe	5·01	277	*Dumf.*	Dumfries, Crichton R.I.	7·43	231
N'hant	Wellingboro', Swanspool	3·79	205	,,	Eskdalemuir Obsy.	10·24	190
Essex	Shoeburyness	2·71	201	*Roxb.*	Kelso, Floors	6·04	345
Suffolk	Campsea Ashe, High Ho.	3·41	187	*Peebles.*	Stobo Castle	6·84	228
,,	Lowestoft Sec. School	3·69	264	*Berwick*	Marchmont House	7·08	315
,,	Bury St. Ed., Westley H.	4·29	240	*E. Loth.*	North Berwick Res.	5·44	316
Norfolk	Sandringham Ho. Gdns.	4·06	209	*Midl'n.*	Edinburgh, Blackf'd. H.	5·27	299
Wilts.	Bishops Cannings	5·95	256	*Lanark*	Hamilton W. W., T'nhill	6·17	187
Dorset	Creech Grange	6·85	210	*Ayr*	Colmonell, Knockdolian	7·40	171
,,	Beaminster, East St.	7·87	226	,,	Glen Afton, Ayr San.	10·27	201
Devon	Teignmouth, Den Gdns.	6·59	226	*Bute*	Rothesay, Ardencraig	7·14	159
,,	Cullompton	7·86	243	*Argyll*	L. Sunart, Glenborrodale	8·50	120
,,	Barnstaple, N. Dev. Ath.	5·90	180	,,	Poltalloch	7·01	139
,,	Okehampton, Uplands	10·86	213	,,	Inveraray Castle	11·90	145
Cornwall	Bude School House	6·44	212	,,	Islay, Eallabus	8·22	176
,,	Penzance, Morrab Gdns.	7·96	210	,,	Tiree	6·57	155
,,	St. Austell, Trevarna	9·45	221	*Kinross*	Loch Leven Sluice	5·72	182
,,	Scilly, Tresco Abbey	5·96	190	*Fife*	Leuchars Airfield	4·07	224
Glos.	Cirencester	5·09	203	*Perth*	Loch Dhu	11·25	124
Salop	Church Stretton	5·76	221	,,	Crieff, Strathearn Hyd.	5·31	133
,,	Cheswardine Hall	5·44	246	,,	Blair Castle Gardens	4·73	142
Staffs.	Leek, Wall Grange, P.S.	5·74	199	*Angus*	Montrose, Sunnyside	3·85	193
Worcs.	Malvern, Free Library	4·80	217	*Aberd.*	Balmoral Castle Gdns.	3·71	134
Warwick	Birmingham, Edgbaston	4·52	224	,,	Dyce, Craibstone	4·70	199
Leics.	Thornton Reservoir	4·31	218	,,	Fyvie Castle	2·87	121
Lincs.	Boston, Skirbeck	3·76	232	*Moray*	Gordon Castle	1·24	61
,,	Skegness, Marine Gdns.	3·53	204	*Nairn*	Nairn, Achareidh	2·10	116
Notts.	Mansfield, Carr Bank	5·04	234	*Inv's*	Loch Ness, Foyers	3·95	94
Ches.	Bidston Observatory	5·73	270	,,	Glenquoich	13·28	97
Lancs.	Manchester, Whit. Park	7·37	294	,,	Fort William, Teviot	7·95	82
,,	Stonyhurst College	8·80	206	,,	Skye, Duntuilm	5·65	107
,,	Blackpool	6·99	256	*R. & C.*	Ullapool	4·81	108
Yorks.	Wakefield, Clarence Pk.	5·40	281	,,	Applecross Gardens	5·46	100
,,	Hull, Pearson Park	4·26	237	,,	Achnashellach	9·41	103
,,	Felixkirk, Mt. St. John	5·66	283	,,	Stornoway Airfield	5·45	111
,,	York Museum	4·73	267	*Suth.*	Lairg	5·58	170
,,	Scarborough	4·56	228	,,	Loch More, Achfary	9·98	137
,,	Middlesbrough	5·48	342	*Caith.*	Wick Airfield	3·95	161
,,	Baldersdale, Hury Res.	8·42	259	*Shet.*	Lerwick Observatory	4·79	112
Nor'ld	Newcastle, Leazes Pk.	8·01	404	*Ferm.*	Crom Castle	6·29	189
,,	Bellingham, High Green	8·51	298	*Armagh*	Armagh Observatory	6·72	267
,,	Lilburn, Tower Gdns.	7·21	348	*Down*	Seaforde	8·58	272
Cumb.	Geltsdale	7·48	267	*Antrim*	Aldergrove Airfield	5·61	205
,,	Keswick, High Hill	9·63	191	,,	Ballymena, Harryville	6·19	167
,,	Ravenglass, The Grove	7·96	238	*Lon.*	Garvagh, Moneydig	5·34	155
Mon.	Abergavenny, Larchfield	8·51	252	,,	Londonderry, Creggan	5·86	163
Glam.	Ystalyfera, Wern House	13·73	217	*Tyrone*	Omagh, Edenfel	5·20	147

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, SEPTEMBER 1947

Stations	Pressure: Mean of day M.S.L.	Pressure: Diff. from normal	Temperatures: Absolute Max.	Temperatures: Absolute Min.	Temperatures: Mean values Max.	Temperatures: Mean values Min.	Temperatures: Mean values ½ Max. and Min.	Temperatures: Mean values Diff. from normal	Temperatures: Wet bulb	Relative humidity	Mean cloud amount	Precipitation: Total	Precipitation: Diff. from normal	Precipitation: Days	Bright Sunshine: Daily Mean	Bright Sunshine: Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1018·7	+1·5	77	40	68·9	52·5	60·7	+3·2	57·1	77	6·9	1·17	−0·70	10	5·2	41
Gibraltar	1017·1	−0·1	84	61	80·4	67·8	74·1	+1·7	69·5	82	4·9	1·07	—	2	—	—
Malta	1016·4	+0·1	88	63	83·1	70·2	76·7	+0·7	72·5	68	3·4	0·24	—	3	9·3	75
St. Helena	1018·5	—	67	51	60·5	52·7	56·6	−0·3	53·1	98	9·7	4·93	+2·68	25	—	—
Freetown, Sierra Leone	1012·9	+2·3	87	71	83·3	74·4	78·9	+1·6	75·3	89	8·6	30·01	+1·53	27	4·0	33
Lagos, Nigeria ..	1013·4	+1·2	88	68	84·0	71·0	77·5	−1·2	74·9	88	9·2	7·50	—	22	2·9	24
Kaduna, Nigeria ..	1012·0	—	90	63	84·3	66·5	75·4	−0·5	70·9	81	8·4	6·96	−4·54	18	5·3	43
Chileka, Nyasaland																
Salisbury, Rhodesia ..																
Cape Town ..	1020·3	+1·2	82	41	67·6	52·0	59·8	+1·9	52·9	74	5·9	1·35	−0·89	9	—	—
Germiston, South Africa	1019·2	—	83	38	72·2	48·3	60·3	—	47·5	45	2·5	0·41	—	7	9·1	77
Mauritius																
Calcutta, Alipore Obsy.	1004·3	−0·2	96	76	90·7	79·6	85·1	+1·9	79·9	90	7·9	14·00	+3·99	18	5·0	41
Bombay	1005·0	−2·0	89	68	85·4	76·6	81·0	+0·1	76·4	90	8·3	25·45	+14·77	25	3·2	26
Madras	1005·9	−0·6	99	72	91·8	76·8	84·3	−0·9	75·8	78	8·2	5·33	+0·48	12	5·4	44
Colombo, Ceylon ..	1010·3	+0·4	87	73	84·2	76·1	80·1	−1·1	75·5	85	8·8	7·31	+2·55	13	5·4	44
Singapore	1009·5	−0·3	91	71	87·3	74·4	80·9	−0·2	78·3	87	—	10·83	+4·04	15	—	—
Hongkong	1009·5	+1·2	92	73	85·6	77·0	81·3	+0·3	77·3	85	—	17·70	+8·01	21	5·6	45
Sydney, N.S.W. ..	1018·7	+2·6	82	42	68·3	51·2	59·7	+0·5	53·1	62	5·0	0·77	−2·09	6	8·0	67
Melbourne	1017·0	+1·2	76	35	62·9	45·1	54·0	−0·1	48·9	66	7·2	2·20	−0·24	17	4·7	40
Adelaide	1018·7	+1·2	82	41	64·3	47·6	55·9	−1·3	50·3	60	5·9	1·85	−0·23	12	5·5	47
Perth, W. Australia	1019·5	+1·5	79	39	67·0	47·5	57·3	−0·9	53·1	62	4·0	3·19	−0·23	15	7·7	65
Coolgardie	1019·7	+2·5	88	36	72·5	45·7	59·1	+0·4	48·5	53	2·1	0·61	−0·06	5	—	—
Brisbane	1019·5	+1·9	81	47	74·0	56·5	65·3	+0·1	58·5	64	5·2	2·93	+0·93	13	6·9	58
Hobart, Tasmania ..	1010·9	−0·1	73	35	60·0	42·3	51·1	+0·1	45·2	61	6·8	1·63	−0·44	9	6·6	56
Wellington, N.Z. ..	1014·6	0·0	64	36	56·6	44·8	50·7	+0·6	48·2	76	7·1	5·49	+1·52	13	5·9	50
Suva, Fiji	1015·1	+0·8	84	65	79·5	70·0	74·7	+0·2	71·1	82	7·7	8·55	+0·86	22	4·5	37
Apia, Samoa ..	1012·5	+0·3	89	70	86·3	74·0	80·1	+1·9	76·7	76	5·5	10·23	+5·12	20	8·0	67
Kingston, Jamaica ..	1013·4	+1·2	94	71	87·7	74·7	81·2	−0·3	75·8	78	4·7	10·31	+6·28	13	7·6	62
Grenada, W. Indies	1012·8	+1·0	88	72	87·1	75·9	81·5	+1·2	78·1	79	6·3	6·06	−1·93	26	—	—
Toronto	1019·9	+2·1	87	34	72·7	53·8	63·3	+3·0	55·1	82	3·6	1·79	−0·88	8	7·1	57
Winnipeg	1015·8	+2·0	88	21	64·4	41·9	53·1	−0·6	42·0	87	5·2	0·85	−1·37	11	5·5	43
St. John, N.B. ..	1020·1	+2·7	82	34	65·7	49·9	57·8	+1·9	52·6	86	5·9	2·21	−1·53	10	6·4	51
Victoria, B.C. ..	1018·2	+1·8	78	36	68·2	46·4	57·3	+1·2	48·3	90	3·3	1·15	−0·66	7	7·6	60